Effect of model incompleteness on auto-correlation based calibration in 21-cm cosmology experiments

Abstract

Precision calibration of the instruments (radio interferometric arrays or single-element radiometers) pose crucial challenges in 21-cm cosmology experiments aiming to probe the redshifted 21-cm signal of neutral hydrogen from Cosmic Dawn and Epoch of Reionization (z~30-6). In this work, we use simulations to study the effect of model incompleteness in auto-correlation (or total power) based calibration of instruments with two types of receiver designs, HERA type dish and EDGES type dipole. We investigate various model incompleteness effects such as variations in instrumental gain (per antenna gain) in time, incomplete sky-model used for calibration, and primary beam inaccuracies. We find that temporal gain drifts, sky-model incompleteness, and beam inaccuracies cause biases in the receiver gain amplitude and the receiver temperature. We show that bias due to temporal gain variation can be mitigated to a great extent by incorporating a time dependent gain-model in calibration, but leads to larger errors on the receiver gain and temperature obtained from calibration. However, more accurate sky-model and primary beam models are required to avoid any bias due to sky incompleteness and beam inaccuracy.